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HANDBOOK OF INSTRUCTIONS

for

MODEL 541A
CRYSTAL IMPEDANCE METER
(SIGNAL CORPS MODEL TS-710/TSM)

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QTLY. C. CAL.
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RADIO FREQUENCY LABORATORIES, INC.
BOONTON, NEW JERSEY

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MODEL 541A

CRYSTAL IMPEDANCE METER

(SIGNAL CORPS MODEL TS-710/TSM)

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RADIO FREQUENCY LABORATORIES, INC.

BOONTON, NEW JERSEY

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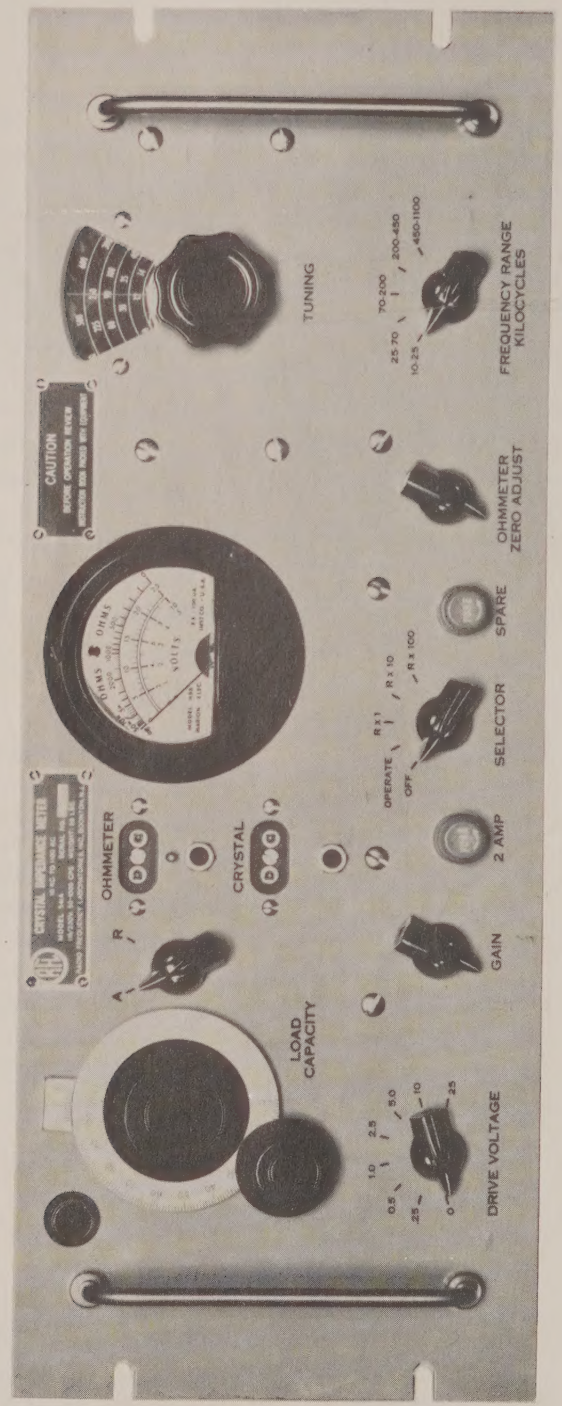


Figure 1. Front Panel View of Crystal Impedance Meter Model 541 A

SECTION I
GENERAL DESCRIPTION

1. PURPOSE OF HANDBOOK.

The purpose of this handbook is to provide operating and servicing personnel with the necessary information concerning the installation, operation and maintenance of the Crystal Impedance Meter Model 541A.

2. PURPOSE OF EQUIPMENT.

The Crystal Impedance Meter Model 541A is designed to measure directly the effective resonance and anti-resonance resistance of quartz crystal units in the frequency range of 10-1100 kilocycles.

3. GENERAL DESCRIPTION.

The Crystal Impedance Meter Model 541A is equivalent in all respects to the Signal Corps Crystal Impedance Meter TS-710/TSM.

The Model 541A Crystal Impedance Meter consists of a two-tube resistance-capacitance coupled oscillator covering a frequency range of 10 to 1100 kilocycles in five bands. An internal calibrated load capacitor allows the unit to measure directly the effective resonance and anti-resonance resistance of quartz crystal units.

A built-in vacuum tube voltmeter measures the voltage across the crystal unit and enables the operator to determine the power dissipated in the crystal unit. For convenience in measuring the resistance of the variable resistance adapters during the test procedure, an ohmmeter is also included in the equipment. Furnished with the equipment is a 5 foot output cable with plug attached, fourteen fixed calibrating resistors, and three variable resistance adapters. The three variable adapters have maximum resistance values of 5 K, 50 K and 500 K. Two other adapters are furnished that allow the testing of crystal units contained in HC-5/U and octal base holders. All the fixed resistors and adapters are contained in a small painted metal box approximately 7-1/2 x 5 x 2 inches.

The C.I. Meter operates from a single phase power source of 115 or 230 volts AC, 50 to 1000 cycles per second.

The unit is housed in a grey smooth-finished metal case designed for rack mounting. The over-all dimensions of the unit are 19'' long by 10-1/2'' wide by 7'' high.

4. DESCRIPTION OF MINOR COMPONENTS.

a. Fourteen plastic encased calibrating resistors, with pin connections to match the spacing of the crystal socket and having values of 3K, 4K, 5K, 6K, 7K, 8K, 10K, 20K, 50K, 75K, 100K, 125K, 150K, 200K ohms are supplied. These resistors are within ±1% of the nominal value.

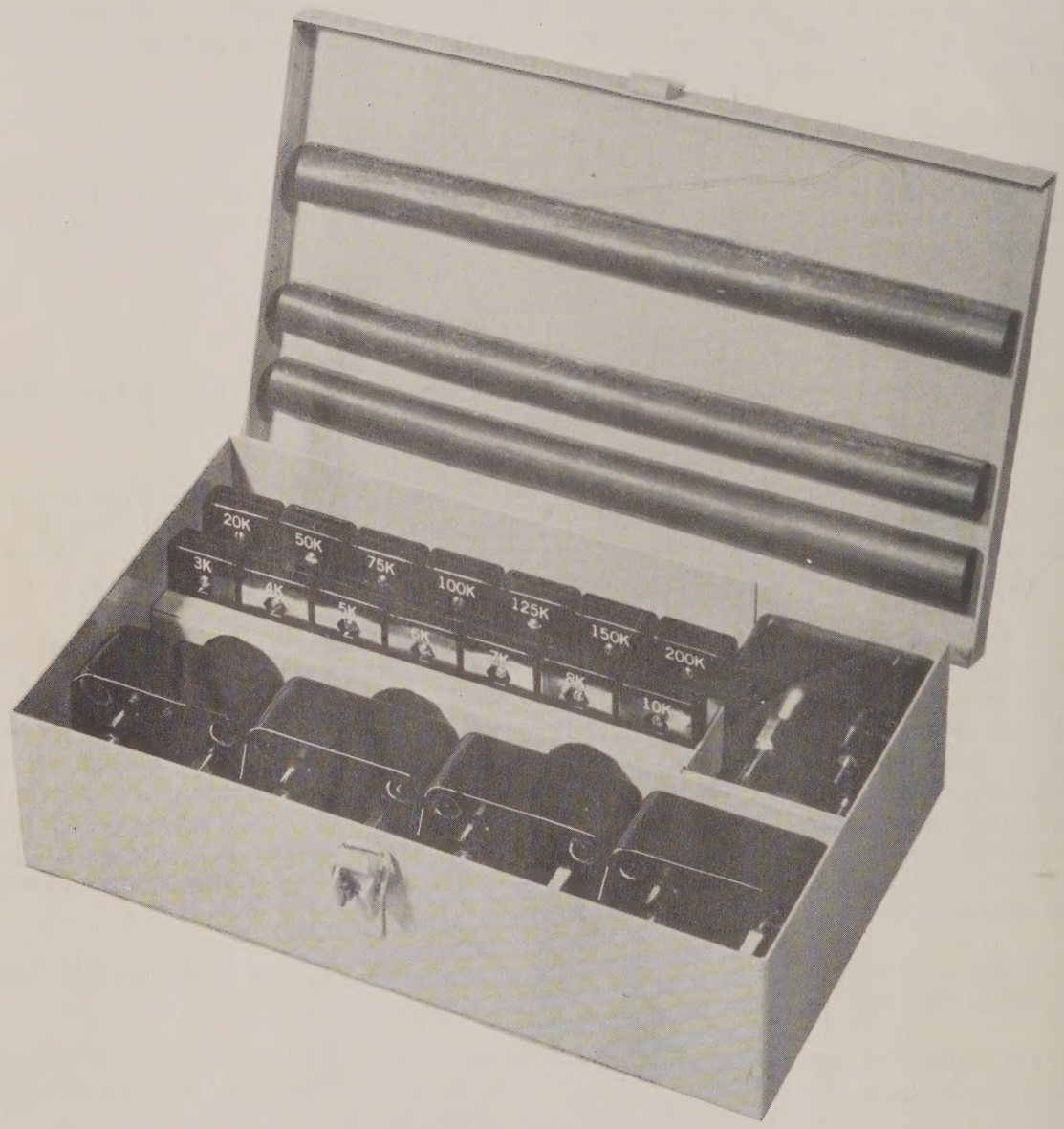


Figure 2. Calibrating Resistors and Adapters

b. Three variable calibrating resistors are also supplied. These adapters contain composition rheostats with maximum values of 5K, 50K, and 500K ohms. The adapters have pin connectors so that they may be plugged into the CRYSTAL or OHMMETER sockets.

c. Two other adapters are supplied. One allows the use of crystal units in HC-5/U holders to be plugged into the CRYSTAL socket. The other adapter performs the same function for crystal units mounted in octal base holders.

d. A 5-foot r-f output cable assembly is also supplied. The cable has a UG-88/U connector on one end, the other end has no termination.

5. TECHNICAL CHARACTERISTICS.

The characteristics of Crystal Impedance Meter Model 541A are as follows:

Frequency range	Five ranges:	10-25 KC 25-70 KC 70-200 KC 200-450 KC 450-1100 KC
Voltmeter range	0.25 to 25 volts full-scale	
Ohmmeter range	10 ohms to 5 megohms	
Resistance calibration	Fourteen calibrating resistors with values of 3K, 4K, 5K, 6K, 7K, 8K, 10K, 20K, 50K, 75K, 100K, 125K, 150K, 200K and three variable resistance adapters with maximum resistance values of 5 K, 50 K and 500 K.	
Number of tubes	6.	

Driver amplifier	V1	6005
Phase-inverter-amplifier	V2	5749
Voltmeter	V3	5751
Rectifier	V4	5Y3W
Voltage regulator	V5	0B2
Voltage regulator	V6	0A2

Required power source ..... 115 or 230 volts AC, 50 to 1000 cps, 55 watts.

SECTION II
INSTALLATION AND ADJUSTMENT

1. UNPACKING THE EQUIPMENT.

Cut the metal bands. Open the cartons that protect the equipment; or, if heavy wrapping paper has been used, remove it carefully and take out the components. Check the contents of the packing case against the master packing slip.

CAUTION

BE CAREFUL IN UNPACKING AND HANDLING EQUIPMENT; IT IS EASILY DAMAGED. IF IT BECOMES DAMAGED OR EXPOSED, A COMPLETE OVERHAUL MIGHT BE REQUIRED OR EQUIPMENT MIGHT BE RENDERED USELESS.

Note. Save the original packing cases and containers. They can be used again when the equipment is repacked for storage or shipment.

2. INSTALLATION OF EQUIPMENT.

The following steps should be followed in the installation of the equipment:

a. Check the contents of the packing case against the master packing list.

b. Thoroughly inspect the exterior of the Crystal Impedance Meter for possible damage in shipment.

c. Loosen the nine binding head screws on the sides and back of the unit and remove the metal dust cover. Also remove the bottom cover plate.

d. Make sure no vacuum tubes are broken and that they are properly seated in their sockets.

e. Inspect the wiring to make certain that the leads are securely fastened to points of contact.

f. Inspect the sub-assembly parts such as terminal strips to make certain they are securely fastened in place.

g. Remove the cap from the fuse holders on the panel of the unit (figure 1) and see that the fuses (2-ampere) have been installed.

h. Replace the dust cover and bottom cover plate.

CAUTION

THE CHASSIS OF THE CRYSTAL IMPEDANCE METER HAS BEEN MOISTUREPROOFED AND FUNGIPROOFED. DO NOT REMOVE ANY OF THE PROTECTIVE COATING.

3. CONTROLS AND INSTRUMENTS.

a. GENERAL. - Haphazard operation or improper setting of the controls can cause damage to electronic equipment. For this reason it is important to know the function of every control. The actual operation of the equipment is discussed in Section III.

CAUTION

IT IS OF GREAT IMPORTANCE THAT THE LINE "VOLTAGE CHANGE-OVER" SWITCH S6 ON THE REAR OF THE UNIT BE CORRECTLY SET AND LOCKED IN THE OPERATING VOLTAGE POSITION.

b. CONTROLS AND THEIR FUNCTIONS. - The following table lists controls of the Crystal Impedance Meter and indicates their functions.

TABLE 2—1. CONTROLS AND THEIR FUNCTIONS

CONTROL	FUNCTION
LOAD CAPACITY	Calibrated dial varies load capacitor from 16 to 110 mmf.
A-R	Switch across load capacitor. In the A position the capacitor is in series with the crystal socket and in the R position the capacitor is shorted out of the circuit.
DRIVE VOLTAGE	Step voltage divider that adjusts the voltage across the crystal unit.
GAIN	Varies the loop gain of the oscillator circuit.

TABLE 2—1. CONTROLS AND THEIR FUNCTIONS, (CONT'D)

CONTROL	FUNCTION
SELECTOR	Contains the AC power switch and circuits to energize either the oscillator or ohmmeter circuits.
OHMMETER ZERO ADJUST	Sets the ohmmeter zero on each of the three resistance ranges.
FREQUENCY RANGE KILOCYCLES	Band switch selects correct coil for frequency range.
TUNING	Varies tuning capacitor to cover frequency range.

There is one other switch on the front panel. It is located just below the OHMMETER socket. In its normal position it is normally closed and places a short across the OHMMETER socket. This facilitates the zero adjustment on the three ohmmeter ranges. When an adapter is inserted into the socket, it pushes the button in and opens the switch. The ohmmeter then reads the resistance of the adapter.

4. INITIAL ADJUSTMENT OF EQUIPMENT.

All initial adjustments of the Crystal Impedance Meter Model 541A are made at the factory and field adjustments should be unnecessary.

SECTION III
OPERATION

1. STARTING PROCEDURE.

a. Set DRIVE VOLTAGE control to 0.

b. Set GAIN control fully counter-clockwise.

c. Set SELECTOR switch to OFF.

d. Determine whether the power source is 115 or 230 volts, and lock the Voltage Change-Over switch (located on back of chassis) in the proper position.

e. Insert the power cord into the AC outlet.

2. OPERATING PROCEDURE.

a. MEASUREMENT OF RESONANCE RESISTANCE.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Crystal Impedance Meter to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to set the meter to the frequency of the crystal unit. Note that the markings on the tuning dial are only approximate frequency values, they are not for precise frequency measurement.

(3) Rotate the A-R switch to R.

(4) Insert the crystal unit into the CRYSTAL socket.

(5) Rotate the DRIVE VOLTAGE control to .25. The markings on the DRIVE VOLTAGE control correspond to the three scales on the voltmeter; i.e., the .25 position is read on the 25 volt scale and the readings are divided by 100.

(6) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(7) If no meter indication is obtained with the GAIN control rotated to its full clockwise position, rotate the control counter-clockwise and advance the DRIVE VOLTAGE control to the 0.5 or next position.

(8) Repeat steps (6) and (7) until an adequate meter indication is obtained, and adjust the TUNING knob for maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

CAUTION

SOME CRYSTAL UNITS TESTED IN THIS UNIT MAY BEGIN TO OSCILLATE VERY SLOWLY AND THEN BUILD UP QUICKLY. THEREFORE, IT IS NECESSARY TO ADVANCE THE GAIN CONTROL SLOWLY DURING THIS PROCEDURE. AT TIMES IT IS ALSO NECESSARY, AS SOON AS THE CRYSTAL UNIT STARTS TO OSCILLATE, TO ROTATE THE GAIN CONTROL COUNTER-CLOCKWISE (REDUCING THE DRIVING VOLTAGE) TO KEEP THE CRYSTAL UNIT FROM SHATTERING.

(9) Connect the RF cable from output jack J-1 (on the back of the chassis) to a suitable frequency measuring device. (An electronic frequency counter is very convenient in this application.) Obtain an approximate measurement of the crystal frequency.

(10) Replace the crystal unit with the 50 K variable resistance adapter (set at maximum resistance, counter-clockwise) and adjust the adapter for the same voltmeter indication that was obtained with the crystal unit. If the 50 K adapter is of too low a resistance (meter goes off-scale), use the 500 K adapter, starting at the maximum resistance. Retune the Crystal Impedance Meter for zero-beat or the same output frequency that was obtained with the crystal unit.

(11) Remove the calibrating resistor and replace with the crystal unit. Use the GAIN control to adjust the voltmeter to a convenient reading and retune the frequency measuring equipment for zero-beat.

(12) Repeat steps (10) and (11) until the meter readings and output frequencies are the same for both the crystal unit and the calibrating resistor.

(13) In order to measure the resistance of the calibrating resistor (which is now equal to the effective crystal resonance resistance), rotate the SELECTOR switch to the R x 1 position and rotate the OHMMETER ZERO ADJUST control until the meter reads zero ohms. Insert the calibrating resistor firmly into the OHMMETER socket. If a small meter indication is obtained, pull the resistor out about one-quarter inch or until the meter reads zero, and advance the SELECTOR switch to the R x 10 or R x 100 position, and zero meter if necessary. Again push the resistor firmly into the socket to obtain the ohmmeter reading.

(14) In order to find the power dissipated in the crystal unit, use the following formula:

$$P = \frac{E^2}{R}$$

where:

P = Power in watts,
E = Voltmeter reading in volts,
R = Effective crystal resonance resistance in ohms.

(15) An accurate measurement of the crystal unit's operating frequency now can be made. Connect the RF cable from jack J-1 (on the back of the chassis) to a suitable frequency measuring device. Plug the crystal unit into the CRYSTAL socket and rotate the SELECTOR switch to the OPERATE position.

The frequency of the crystal unit at the calculated drive level (para. (14)) may now be measured.

(16) If the operating frequency or resonance resistance is to be determined at some other drive level, calculate the required voltage across the crystal unit using the formula:

$$E = \sqrt{PR}$$

where:

E = Voltage across the crystal unit in volts (voltmeter reading),
P = Drive level in watts,
R = Crystal unit effective resonance resistance in ohms as determined from above procedure.

Then repeat the above operating procedure from paragraphs (1) to (13) and (15), except that in paragraphs (8) and (11) set the drive voltage at the above calculated voltage (para. (16)) and continue with the remainder of the procedure. If wide variations are found in the resistance of the crystal unit, from paragraphs (16) and (19), a more accurate measurement may be made by repeating the above procedure once more so that the resistance values are more alike.

b. MEASUREMENT OF ANTI-RESONANCE RESISTANCE.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Crystal Impedance Meter to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit. Note that the markings on the tuning dial are only approximate frequency values, they are not for precise frequency measurements.

(3) Rotate the A-R switch to A.

(4) Adjust the LOAD CAPACITY dial to the proper setting. Calibration data are given in the calibration chart supplied with the instrument.

(5) Insert the crystal unit into the CRYSTAL socket.

(6) Set the DRIVE VOLTAGE control to the .25 position. The markings on the DRIVE VOLTAGE control correspond to the three scales on the voltmeter, i.e., the .25 position is read on the 25 volt scale and the readings are divided by 100.

(7) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(8) If no meter indication is obtained with the GAIN control rotated to its full clockwise position, rotate the control counter-clockwise and advance the DRIVE VOLTAGE control to the 0.5 or next position.

(9) Repeat steps (7) and (8) until an adequate meter indication is obtained, and adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

CAUTION

SOME CRYSTAL UNITS TESTED IN THIS UNIT MAY BEGIN TO OSCILLATE VERY SLOWLY AND THEN BUILD UP QUICKLY. THEREFORE, IT IS NECESSARY TO ADVANCE THE GAIN CONTROL SLOWLY DURING THIS PROCEDURE. AT TIMES IT IS ALSO NECESSARY, AS SOON AS THE CRYSTAL UNIT STARTS TO OSCILLATE, TO ROTATE THE GAIN CONTROL COUNTER-CLOCKWISE (REDUCING THE DRIVING VOLTAGE) TO KEEP THE CRYSTAL UNIT FROM SHATTERING.

(10) Connect the RF cable from output jack J-1 (on the back of the chassis) to a suitable frequency measuring device. (An electronic frequency counter is very convenient in this application.) Obtain an approximate measurement of the crystal frequency.

(11) Remove the crystal unit and rotate the A-R switch to the R position.

(12) Insert the 50K variable resistance adapter in the CRYSTAL socket (set at maximum resistance) and adjust the adapter for the same voltmeter indication that was obtained with the crystal unit. If the 50 K adapter is of too low a resistance (meter goes off-scale), use the 500 K adapter starting at maximum resistance. Retune the Crystal Impedance Meter for zero-beat or the same output frequency that was obtained with the crystal unit.

(13) Set the A-R switch to A.

(14) Remove the calibrating resistor and replace with the crystal unit. Use the GAIN control to adjust the voltmeter to a convenient reading and retune the frequency measuring equipment for zero-beat.

(15) Repeat steps (11) through (14) until the meter readings and output frequencies are the same for both the crystal unit and the calibrating resistor.

(16) In order to measure the resistance of the calibrating resistor (which is now equal to the effective anti-resonance resistance of the crystal unit), rotate the SELECTOR switch to the R x 1 position and rotate the OHMMETER ZERO ADJUST control until the meter reads zero ohms. Insert the calibrating resistor firmly into the OHMMETER socket If a small meter indication is obtained, pull the calibrating resistor out about one-quarter inch, or until the meter reads zero ohms. Advance the SELECTOR swi ch to the R x 10 or R x 100 position and zero meter if necessary. Again push the resistor firmly into the socket to obtain the ohmmeter reading.

(17) In order to find the power dissipated in the crystal unit, use the following formula:

$$P = \frac{E^2}{R_e}$$

where:

P = Power in watts,
E = Voltmeter reading in volts,
R = Effective crystal anti-resonance resistance in ohms.

(18) An accurate measurement of the crystal unit's operating frequency (at anti-resonance) now can be made. Plug the crystal unit into the CRYSTAL socket, rotate the A-R switch to A and the SELECTOR switch to the OPERATE position. Connect the RF cable from jack J-1 (on the back of the chassis) to a suitable frequency measuring device. The frequency of the crystal unit at the calculated drive level (para. (17)) may now be measured.

(19) If the operating frequency or anti-resonance resistance is to be determined at some other drive level, calculate the required voltage across the crystal unit using the formula:

$$E = \sqrt{PR_e}$$

where:

E = Voltage across the crystal unit in volts (voltmeter reading),
P = Drive level in watts,
R = Crystal unit effective anti-resonance resistance in ohms as determined from above procedure.

Then repeat the above operating procedure from paragraphs (1) to (16) and (18), except that in paragraphs (9) and (14) set the drive voltage at the above calculated voltage (para. (19)) and continue with the remainder of the procedure. If wide variations are found in the resistance of the crystal unit, from paragraphs (16) and (19), a more accurate measurement may be made by repeating the above procedure once more so that the resistance values are more alike.

c. PROCEDURE FOR USING CRYSTAL IMPEDANCE METER AS A GO-NO GO GAGE, RESONANCE OPERATION.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Crystal Impedance Meter to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit.

(3) Rotate the A-R switch to R.

(4) Insert the crystal unit into the CRYSTAL socket.

(5) Rotate the DRIVE VOLTAGE control to .25. The markings on the DRIVE VOLTAGE control correspond to the three scales on the voltmeter; i.e., the .25 position is read on the 25 volt scale and the readings are divided by 100.

(6) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(7) If no meter indication is obtained with the GAIN control rotated to its full clockwise position, rotate the control counter-clockwise and advance the DRIVE VOLTAGE control to the 0.5 or next position.

(8) Repeat steps (6) and (7) until an adequate meter indication is obtained, and adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(9) Connect the RF cable from output jack J-1 (on the back of the chassis) to a suitable frequency measuring device. (An electronic frequency counter is very convenient in this application.) Obtain an approximate measurement of the crystal frequency.

(10) Remove the crystal unit and substitute a fixed calibrating resistor with a value of resistance that corresponds to the maximum permissible resistance of the crystal unit under test, as indicated in the applicable crystal unit specifications.

(11) Determine the drive level required, in watts, and compute the voltage (using the resistance value selected in paragraph (10)) to be used across the crystal unit.

(12) Adjust the GAIN and DRIVE VOLTAGE controls so that the voltmeter reads this computed voltage. Where no drive level has been established, the drive voltage should be maintained at approximately half-scale at the lowest DRIVE VOLTAGE control setting that will enable half-scale operation.

(13) Rotate the TUNING knob so that the signal is at or near zero-beat with the frequency measured in paragraph (9) above.

(14) If necessary, readjust the GAIN control to obtain the computed voltage. This voltage is the passing activity level.

(15) Remove the calibrating resistor.

(16) Crystal units exhibiting a greater voltmeter reading than that obtained in paragraph (14) pass the activity requirements; those giving a smaller voltmeter reading fail.

(17) If high activity (lower resistance) crystal units cause the voltmeter to go off-scale, repeat the above procedure setting the DRIVE VOLTAGE control to the next higher voltage position and reduce the GAIN control setting to obtain the

same computed voltage (para. (11)). This allows the voltmeter pointer to have a greater upswing.

d. PROCEDURE FOR USING CRYSTAL IMPEDANCE METER AS A GO-NO GO GAGE, ANTI-RESONANCE OPERATION.

(1) Set the SELECTOR switch to OPERATE and allow 15 minutes for the Crystal Impedance Meter to warm up.

(2) Set the FREQUENCY RANGE switch to the desired range and rotate the TUNING knob to the approximate frequency of the crystal unit.

(3) Rotate the A-R switch to A.

(4) Adjust the LOAD CAPACITY dial to the proper setting. Calibration data are given in the calibration chart supplied with the instrument.

(5) Insert the crystal unit into the CRYSTAL socket.

(6) Set the DRIVE VOLTAGE control to the .25 position. The markings on the DRIVE VOLTAGE control correspond to the three scales on the voltmeter; i.e., the .25 position is read on the 25 volt scale and the readings are divided by 100.

(7) Slowly advance the GAIN control while rocking the TUNING knob back and forth through the frequency of the crystal unit.

(8) If no meter indication is obtained with the GAIN control rotated to its full clockwise position, rotate the control counter-clockwise and advance the DRIVE VOLTAGE control to the 0.5 or next position.

(9) Repeat steps (7) and (8) until an adequate meter indication is obtained, and adjust the TUNING knob for a maximum meter indication. Adjust the meter to approximately half-scale with the GAIN control.

(10) Connect the RF cable from output jack J-1 (on the back of the chassis) to a suitable frequency measuring device. (An electronic frequency counter is very convenient in this application.) Obtain an approximate measurement of the crystal frequency.

(11) Remove the crystal unit and rotate the A-R switch to the R position.

(12) Insert in the CRYSTAL socket a fixed calibrating resistor with a value of resistance that corresponds to the maximum permissible resistance of the crystal unit under test, as indicated in the applicable crystal unit specifications.

(13) Determine the drive level, in watts, and compute the voltage (using the resistance value selected in para. (12)) to be used across the crystal unit.

(14) Adjust the GAIN and DRIVE VOLTAGE controls so that the voltmeter

reads this computed voltage. Where no drive level has been established, the drive voltage should be maintained at approximately half-scale at the lowest DRIVE VOLTAGE control setting that will enable half-scale operation.

(15) Rotate the TUNING knob so that the signal is at or near zero-beat with the frequency measured in paragraph (10) above.

(16) If necessary, readjust the GAIN control to obtain the computed voltage. This voltage is the passing activity level.

(17) Remove the calibrating resistor.

(18) Rotate the A-R switch to A.

(19) Crystal units exhibiting a greater voltmeter reading than that obtained in paragraph (16) pass the activity requirements; those giving a smaller voltmeter reading fail.

(20) If high activity (lower resistance) crystal units cause the voltmeter to go off-scale, repeat the above procedure setting the DRIVE VOLTAGE control to the next higher voltage position, and reduce the GAIN control setting to obtain the same computed voltage, paragraph (13). This allows the voltmeter pointer to have a greater upswing.

SECTION IV
THEORY OF OPERATION

1. CRYSTAL PARAMETERS, GENERAL.

a. PIEZOELECTRIC EFFECT. - When an electrical stress is applied to a cut quartz crystal in the direction of one of the major axes, a mechanical stress is produced at right angles to this axis. Conversely, a mechanical stress along a major axis will cause electrical charges to appear on the faces of the crystal perpendicular to the stress axis. The polarity of the electrical stress and the direction of the corresponding mechanical force are interrelated, a reversal in one causes a reversal in the other. This relationship between electrical stress and mechanical force is termed the piezoelectric effect and provides a means of relating mechanical vibrations to electrical circuits.

b. RESONANCE. - An alternating voltage applied across a quartz crystal will cause the crystal to vibrate. If the frequency of the applied alternating voltage approximates a frequency at which mechanical resonance can exist in the crystal, the amplitude of the vibrations will be very large. Any crystal has several such resonant frequencies that depend on the crystal dimensions, the type of oscillation involved, and the orientation of the plate cut from the natural crystal.

c. PROPERTIES OF PIEZOELECTRIC RESONATOR. - A good piezoelectric resonator possesses the following properties: a low-temperature coefficient of resonant frequency, a high piezoelectric activity (PI), and a frequency spectrum containing only one resonant frequency in the vicinity of the desired oscillation. Temperature can alter the frequency of mechanical resonance through its effects on the density, the linear dimensions, and the moduli of elasticity of the crystal. Since some of the elastic constants are positive and others are negative, the temperature coefficient of frequency may be either positive, negative, or zero, according to the mode of oscillation, the orientation of the crystal plate, and the shape of the plate. The electrical circuit associated with a vibrating crystal is shown in Figure 3. The capacity C_0 represents the electrostatic capacity between the crystal electrodes when the crystal is in place but not vibrating; the series combination of L, C, and R represents the equivalent mass, compliance, and frictional loss of the vibrating crystal, respectively.

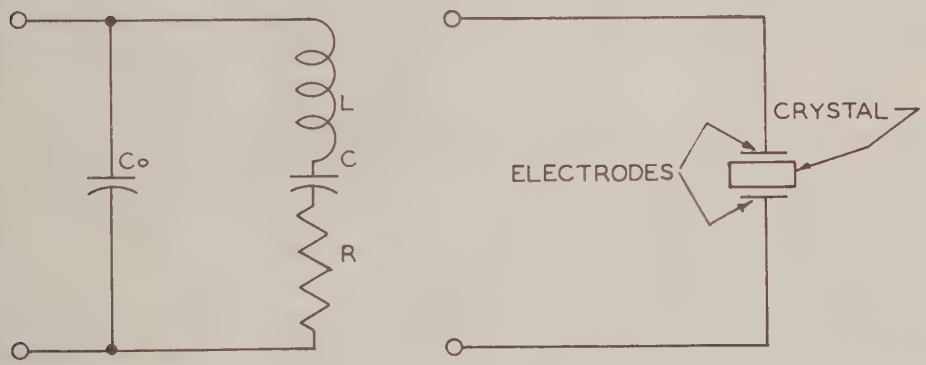


Figure 3. Equivalent Electrical Circuit of a Piezoelectric Crystal.

2. MEASUREMENT.

a. STATIC CAPACITANCE, C_0. - The value of the static capacitance of the crystal unit, C_0, may be measured by any conventional capacitance measuring unit. If this measurement is made with the use of a Q meter or an rf bridge, be careful to select a frequency of operation somewhat lower than the crystal unit frequency. Figure 3 shows a diagram of the parameters of a piezoelectric crystal.

b. RESONANCE AND ANTI-RESONANCE RESISTANCES. - The measurement of the effective resistance in ohms at resonance is outlined in the operation procedure. The measurement of the effective resistance in ohms at anti-resonance is also outlined in the operation procedure.

c. SERIES CAPACITANCE, C. - Use the following equation to calculate the capacitance, C, of the series arm of the crystal unit:

$$C \text{ (in farads)} = \frac{2 (C_0 + C_1) \Delta F}{F}$$

where:

ΔF = the difference between the anti-resonance frequency and the resonance frequency ($F_a - F_r$) in cps,
F = the nominal frequency of the crystal unit in cps,
C_0 = the static capacity of the crystal unit in farads, and,
C_1 = the load capacity in farads.

d. INDUCTANCE L. - Use the following equation to calculate inductance L in the series arm of the crystal:

$$L \text{ (in henries)} = \frac{1}{(2 \pi F)^2 C}$$

where:

F = the nominal frequency of the crystal unit in cps, and,
C = the series capacitance, C, of the crystal unit in farads.

e. VOLTAGE ACROSS THE CRYSTAL UNIT. - Resonance and anti-resonance present two different cases as follows:

(1) In series resonance this voltage may be measured directly by the panel voltmeter.

$$E = RI$$

where:

E = voltage across the crystal unit,
R = effective resonance resistance in ohms, and,
I = rf crystal current, in amperes.

(2) Anti-resonance resistance.

$$E = \frac{E_d}{2 \pi F C_1 R_e} = \frac{I}{2 \pi F C_1}$$

where:

E = voltage across the crystal,
E_d = voltage across the crystal unit and load capacitor C_0 as measured by the panel voltmeter,
F = nominal frequency of the crystal unit, in cps,
C_1 = load capacity, in farads,
R_e = effective anti-resonance resistance, in ohms (Section III, para. 2b), and,
2π = 6.28 (a constant).

f. PERFORMANCE INDEX (PI). - The PI of the crystal unit also may be calculated from the equation:

$$PI = \frac{X_e^2}{R_e} = \frac{1}{(2\pi FC_1)^2 R_e}$$

where:

$$X_e = \frac{1}{2\pi FC_1}$$

3. CRYSTAL IMPEDANCE METER.

The Crystal Impedance Meter Model 541A is designed to measure the equivalent circuit parameters of piezoelectric crystals in the frequency range of 10 to 1100 kilocycles. The unit consists of the following four main circuits:

a. Oscillator
b. Voltmeter
c. Ohmmeter
d. Power Supply

a. OSCILLATOR.

The oscillator consists of a 6005 driver amplifier tube (V1) which can supply a 25 volt maximum undistorted sine-wave signal to the input of the compensated DRIVE VOLTAGE control (S1). At this control the signal may be divided down to obtain the proper drive voltage for the crystal unit. The signal is then applied directly to the crystal unit under test or to the crystal through the calibrated load capacitor (C3). This selection is made by the position of the A-R switch (S2). At this point a calibrating resistor may be substituted for the crystal unit, or crystal and load capacitor, to determine the resonance or anti-resonance resistance of the crystal unit. From there it is applied to the GAIN control (R13) and impressed upon the grid of a 5749 phase-inverter-amplifier tube (V2). Tuning is accomplished by varying capacitor C6 which resonates with L1 or L2; the proper coil being selected for each of five ranges. To complete the oscillator loop, the signal is returned from the plate of the 5749 tube through coupling capacitor C8 to the grid of the 6005 tube.

An added feature of the oscillator is an automatic gain control to compensate for the rapid increase in the amplitude of oscillation as the crystal unit starts to oscillate. This circuit consists of a resistor R12 and diode 1N81 connected to the DRIVE VOLTAGE control (S1). This varies the bias on the grid of the 5749 in such a polarity as to reduce the gain of the tube as the oscillation increases.

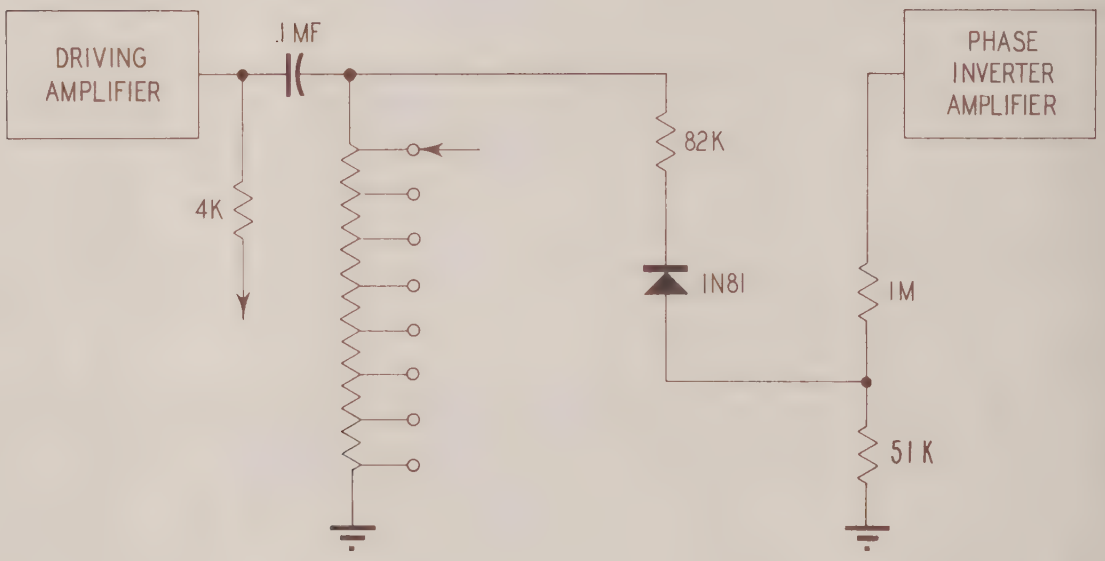


Figure 4. Automatic Gain Control Circuit

b. VOLTMETER.

The voltmeter consists of a 5751 dual triode (V3) connected in parallel, the front panel meter (M1), and a zero adjusting network (R23 and R24). The 5751 tube is self-biased close to cut-off and feeds the meter from the tap of the cathode bias resistors. With no input signal this tap is at a small DC potential. Therefore, in order for the meter to read zero, the negative side of the meter is biased up an equal amount by the divider across the B+ supply. A rheostat (R22) across the meter adjusts it for a full-scale reading with 25 volts input.

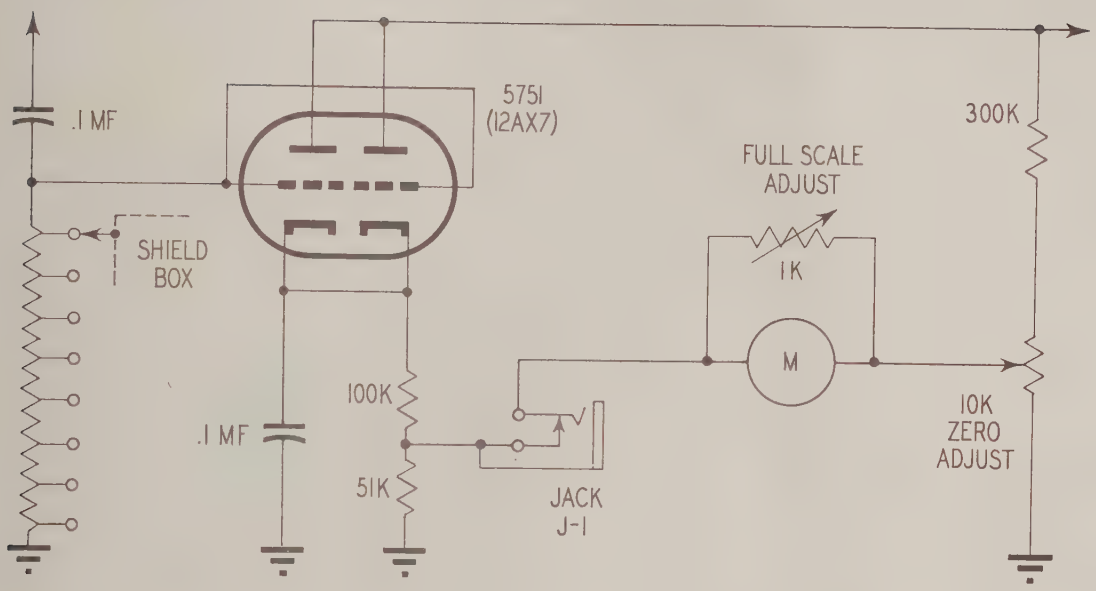


Figure 5. Voltmeter Circuit

As the input voltage to the tube is increased, the average current through the tube also increases and drives the meter. Since the voltmeter is connected to the top of the DRIVE VOLTAGE control, at full-scale it is always supplied with 25 volts RMS. Therefore, in order that the meter may be read at each step of the DRIVE VOLTAGE control, it has three calibrated scales. The full-scale calibrations, times the correct multiplier, correspond to the steps of the DRIVE VOLTAGE control. Any resistance inserted into the CRYSTAL socket constitutes a load on this DRIVE VOLTAGE control. This load tends to produce an error in the reading of the voltmeter due to the loading of the voltage divider. The following table gives the total value of resistance (calibrating resistance plus GAIN control resistance) below which the voltmeter error exceeds 10%.

At the 25 volt position there is no minimum resistance value that would cause a voltmeter error of 10% because at this position there is no voltage divider action. The only limitation on minimum resistance at this position is the stability of the oscillator.

If the GAIN control were set at its minimum resistance position, the resistance values given in the above table would be the minimum values that should be inserted in the CRYSTAL socket for a voltmeter error of 10%. However, in order to obtain a

usable amplitude of oscillation, the GAIN control must be advanced to a higher resistance position, and the minimum inserted resistance may be reduced by the amount of the GAIN control resistance.

TABLE 4—1. RESISTANCE VALUE

DRIVE VOLTAGE RANGE	MINIMUM TOTAL RESISTANCE
VOLTS	OHMS
0.25	225
0.50	425
1.00	875
2.50	2025
5.00	3600
10.00	5400
25.00	----

If crystal unit resistance measurements indicate resistance values lower than those given in the table, and the permissible voltmeter error does not exceed 10%, it is suggested that the equipment voltmeter be disregarded and an external voltmeter be used to measure the voltage with respect to ground at each side of the CRYSTAL socket. To obtain the value of the voltage across the crystal unit, the smaller voltage is subtracted from the larger.

c. OHMMETER.

The ohmmeter consists of a voltage divider system that reduces the regulated potential of 150 volts to the voltage necessary to actuate the meter for the resistance range selected. The SELECTOR switch makes available three resistance ranges R x 1, R x 10, and R x 100. These are read on the single 1000 ohm center scale of the meter.

The lower resistance branch of the voltage dividers is made adjustable so that the center scale reading (1000) may be calibrated for each range. The combination of these three variable resistors and the OHMMETER ZERO ADJUST control allow the ohmmeter to be adjusted at half and full-scale, on each range, for accurate resistance calibration.

Across the OHMMETER socket is a normally closed switch (S5). When the SELECTOR switch is turned to one of the ohmmeter positions, the meter will read zero ohms or can be adjusted to do so, because of this closed switch. The insertion of an adapter into the OHMMETER socket automatically opens this switch and allows the circuit to read the resistance of the adapter.

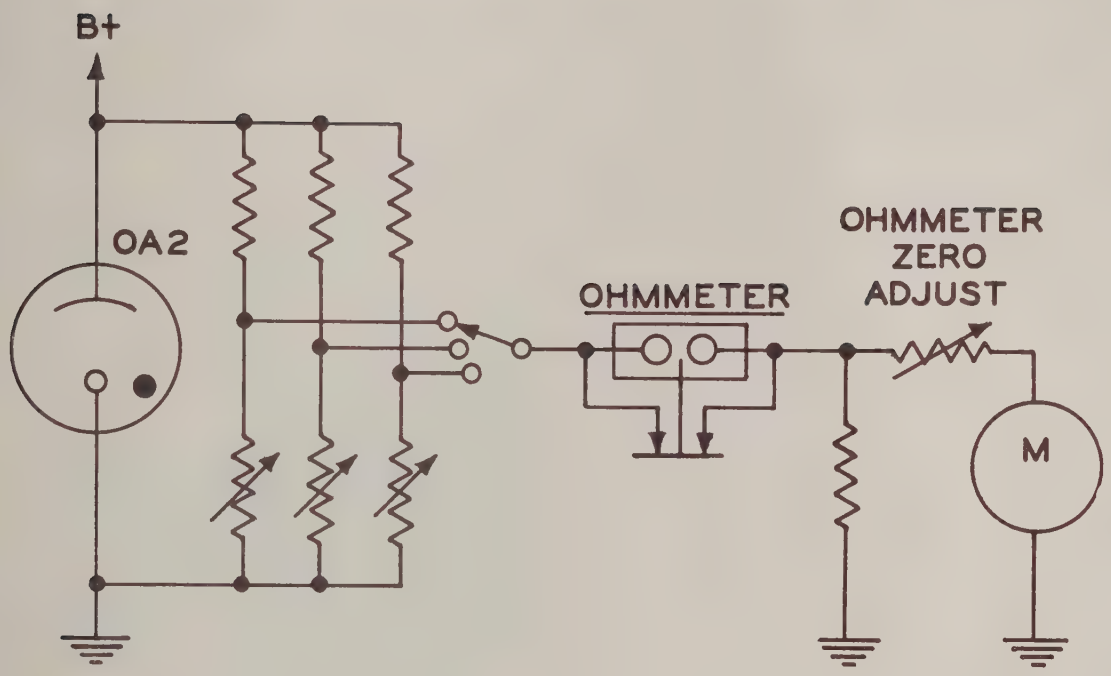


Figure 6. Ohmmeter Circuit

d. POWER SUPPLY.

The power supply is designed to operate from a 115 or 230 volts, 50 to 1000 cycle per second source. A single section choke input filter is followed by a voltage regulator consisting of an 0B2 and an 0A2 tube connected in series and providing 255 volts. The regulator is followed by a two section RC decoupling filter.

SECTION V
MAINTENANCE

1. GENERAL.

Periodic inspection should be made to see that all screws and nuts are tight. If trouble should develop in the sealed meter (M1), it should be replaced from the factory and no attempt made to repair it.

If the tuning dial should become loose and slip, it is only necessary to rotate the variable capacitor to its maximum capacity and align the dial at the low frequency scale-end mark. To obtain better correlation the dial may be rotated slightly in either direction so that all scales are approximately aligned. The dial is not to be used for precise frequency measurement, but only to approximate the crystal unit's frequency until it starts to oscillate.

The LOAD CAPACITOR dial is more critical and should it become loose and slip it is necessary to recalibrate the capacitor. Since this capacitor is calibrated to better than ±.2 μμf the C.I. Meter should be sent back to the factory for recalibration unless proper calibration equipment is available.

2. LOAD CAPACITANCE.

The Load Capacitance Chart is prepared from data obtained by measuring the actual capacitance value (within ±.1 μμf) of the load capacitor in the circuit with the R-A switch in the A position. The equipment required is a 400 kc crystal oscillator controlling a Q meter (Boonton Radio type 100-A, or equal) and a precision capacitor (General Radio type 722-D, or equal). The wiring between the units must be #12 AWG solid copper wire supported on 2 inch centers. The connections to the C.I. Meter are as follows: the high lead of the precision capacitor goes to the set-screw in the R-A switch knob and the ground side goes into the left contact (as you face the equipment) of the CRYSTAL socket.

The Q meter is tuned to resonance by using a standard inductance coil with the precision capacitor set at 200 uuf and the LOAD CAPACITOR dial set at zero. The LOAD CAPACITOR dial is then moved 1 division up at a time from 0 to 10 on the dial, 2 divisions from 10 to 30, and 5 divisions from 30 to 100; the Q meter is retuned to resonance at each point with the precision capacitor. The difference in reading of the precision capacitor is the value of the load capacitor at each dial setting.

3. ADJUSTMENTS.

There are six adjustments on the Model 541A that may be made in the field. They may be broken down into two groups: (a) Voltmeter and (b) Ohmmeter. The five potentiometer adjustments may be reached from the top of the chassis by removing the top dust cover.

a. VOLTMETER.

(1) Loosen shaft locks on R22 and R24.

(2) With power on and the unit non-oscillating, the voltmeter electrical zero may be adjusted by potentiometer R24.

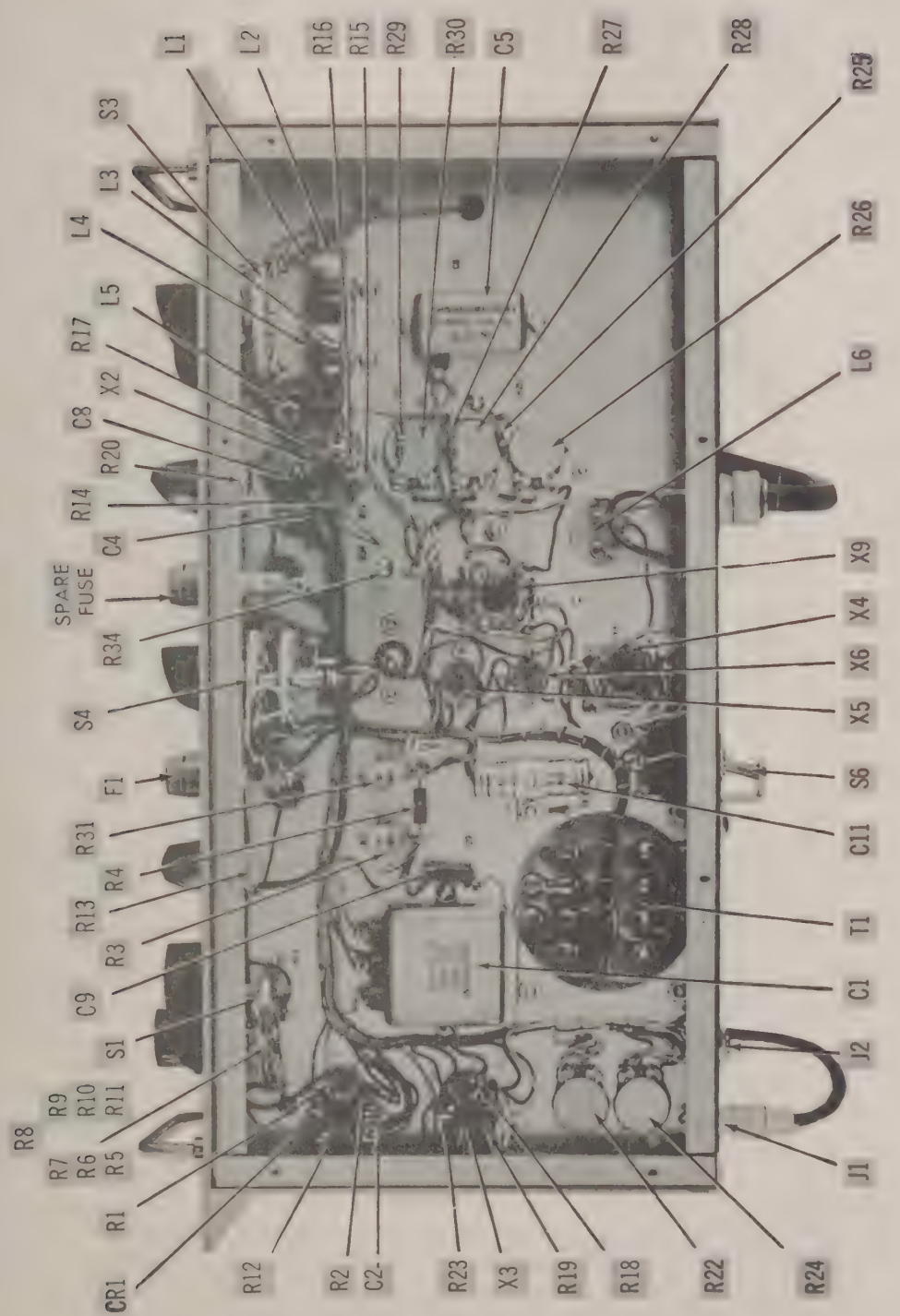


Figure 7. Bottom View of Chassis of Crystal Impedance Meter Model 541A

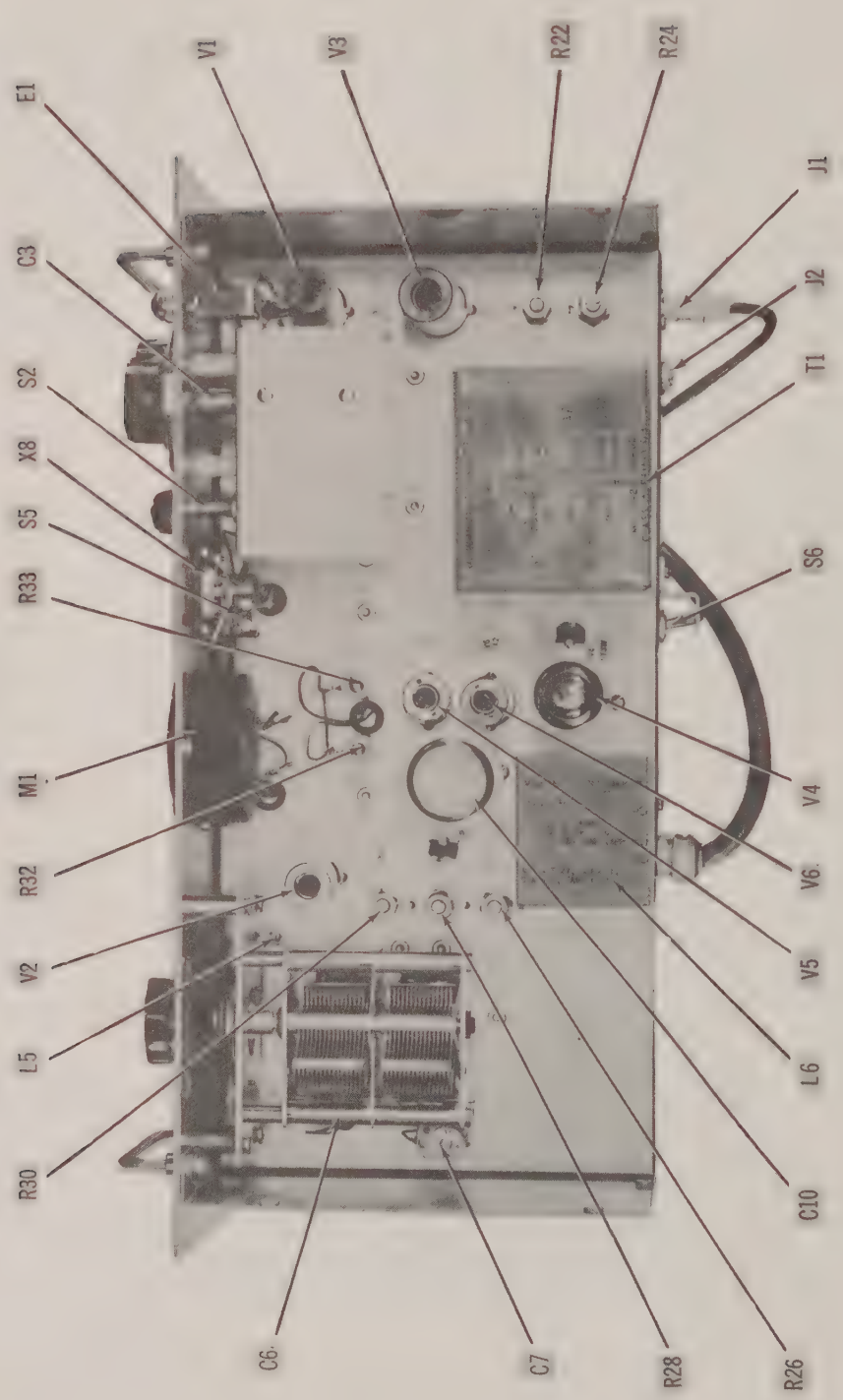


Figure 8. Top View of Chassis of Crystal Impedance Meter Model 541A

(3) With power on and the unit oscillating at 10 kc, adjust voltmeter to full-scale with potentiometer R22, when a VTVM, connected from the junction of R5 and C2 to ground, reads 25 V.

(4) Tighten the shaft locks and recheck.

b. OHMMETER.

(1) Loosen shaft locks on R26, R28, and R30.

(2) a. Set SELECTOR switch to R x 100.
b. Insert a calibrated 100 K resistor into the OHMMETER socket.
c. Rotate the OHMMETER ZERO ADJUST control to its center position.
d. Depress the button under the OHMMETER socket and adjust R26 for a 100 K (1000 x 100) reading.
e. Release button and adjust the OHMMETER ZERO ADJUST control for zero.
f. Repeat steps d. and e. until the ohmmeter reads 100 K with the button down and zero with the button released.

(3) a. Set SELECTOR switch to R x 10.
b. Insert a calibrated 10 K resistor into the OHMMETER socket.
c. Depress button and adjust R28 for a 10 K (1000 x 10) reading.
d. If necessary, readjust the OHMMETER ZERO ADJUST control for a zero reading.
e. Repeat steps c. and d. until the ohmmeter reads 10 K with the button depressed and zero with the button released.

(4) a. Set SELECTOR switch to R x 1.
b. Insert a calibrated 1 K resistor into the OHMMETER socket.
c. Depress the button and adjust R30 for a 1 K reading.
d. If necessary, readjust the OHMMETER ZERO ADJUST control for a zero reading.
e. Repeat steps c. and d. until the ohmmeter reads 1 K with the button depressed and zero with the button released.

(5) Tighten the three shaft locks and recheck.

4. TROUBLE SHOOTING.

WARNING

WHEN SERVICING THE CRYSTAL IMPEDANCE METER MODEL 541A BE EXTREMELY CAREFUL. HIGH VOLTAGE IS PRESENT. ALWAYS DISCONNECT THE LINE PLUG BEFORE MAKING RESISTANCE CHECKS IN THE METER. BEFORE TOUCHING ANY PART AFTER THE VOLTAGE IS SHUT OFF, SHORT THE PART TO CHASSIS.

a. TROUBLE SHOOTING PROCEDURES.

(1) SECTIONALIZATION AND LOCALIZATION. - The first step in servicing a defective test equipment is to sectionalize the fault. Sectionalization means tracing the fault to the major component or circuit responsible for the abnormal operation of the set. The second step is to localize the fault. Localization means tracing the fault to the defective part responsible for the abnormal condition. Some faults, such as burned out resistors and shorted transformers, can be located by sight or smell. The majority of faults may be located by checking voltage and resistance.

(2) TESTS. - The tests listed below aid in isolating the source of trouble. Remember that servicing procedure should cause no further damage to the test equipment. First, trouble should be localized to a single stage or circuit in the equipment. Then the trouble may be isolated within that stage or circuit by appropriate voltage, resistance and continuity measurements.

Through this inspection alone the repairman frequently discovers the trouble or determines the stage in which the trouble exists. This inspection is valuable in order to avoid additional damage which might occur through improper servicing methods and to forestall future failures.

(3) OPERATIONAL TESTS. - The operational tests are important because they frequently indicate the general condition of trouble. In many instances this information will indicate the exact nature of the fault. In order for this information to be utilized fully, all symptoms must be interpreted in relation to another.

The trouble shooting symptoms listed in the chart on page 30 will aid in localizing trouble.

(4) INTERMITTENTS. - In all these tests the possibility of intermittents should not be overlooked. This type of trouble may appear when the set is tapped or jarred. Look for loose connections. It is possible that the trouble is not in the set itself but in the installation, such as cord connections, etc.

5. VOLTAGE MEASUREMENTS.

Voltage measurements are an almost indispensable aid to the repairman because most trouble either results from abnormal voltages or produces abnormal voltages. Voltage measurements are always made between two points in the circuit and the circuit need not be interrupted. Complete information on normal operating voltages is given in the chart on page 29.

(1) Unless otherwise specified, voltages are measured between the indicated points and ground.

(2) Always begin by setting the voltmeter on the highest range in order that the voltmeter will not be overloaded and then, if necessary, set the voltmeter to a lower range.

(3) In checking cathode voltage remember that a reading can be obtained when the cathode resistor actually is open. The resistance of the meter may act as the cathode resistor thus the cathode voltage may be approximately normal only as long as the voltmeter is connected between cathode and ground. An abnormally high plate voltage may indicate an open cathode resistor.

6. VOLTMETER LOADING.

It is essential that the voltmeter resistance be at least ten times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a voltage lower than the actual voltage present when the voltmeter is removed from the circuit.

(1) To minimize voltmeter loading in high resistance circuits, use the highest voltmeter range. The decreased loading caused by the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.

(2) The voltage and resistance charts, Tables 5-1 and 5-2, are based on readings taken with a 20,000 ohms per volt meter. If a 20,000 ohms per volt meter is used in testing for the voltage, it is not necessary to consider the effect of loading.

7. RESISTANCE MEASUREMENTS.

When a fault develops in a circuit its effect will very often show up as a change in the resistance values. Table 5-1 indicates the normal resistance values as measured at the tube sockets. These values are measured between the indicated points and ground unless otherwise stated. Before making any resistance measurements, turn off the power. If the ohmmeter is connected to a circuit which already has voltage in it, the meter may be damaged.

CAUTION

ALWAYS DISCHARGE HIGH VOLTAGE CAPACITORS BEFORE MAKING RESISTANCE MEASUREMENTS.

8. TUBE CHECKING.

Tube faults are responsible for a large percentage of the failures which occur in test equipment. In putting a new tube into the voltmeter circuit, it may be necessary to re-align the voltmeter.

9. GENERAL PRECAUTIONS.

Whenever the C.I. Meter is serviced, carefully observe the following precautions.

TABLE 5—1. RESISTANCE CHART

TUBE	LOCATION	PIN #1	PIN #2	PIN #3	PIN #4	PIN #5	PIN #6	PIN #7	PIN #8	PIN #9
6005	X1	100K	220	.1K	.1K	300K	300K	100K		
5749	X2	1.05M	68	.1	.1	300K	400K	68		
5751	X3	300K	2500	105K	.1	.1	300K	2500	105K	.1
5Y3W	X4	N.C.	300K	N.C.	305	N.C.	305	N.C.	300K	
0B2	X5	300K	N.C.	N.C.	N.C.	300K	N.C.	150K		
0A2	X6	150K	N.C.	N.C.	N.C.	150K	N.C.	0		

Resistance (in ohms) to Ground

K = 1000 ohms
M = 1 megohm

TABLE 5—2 VOLTAGE CHART

SELECTOR switch in OPERATE position

CRYSTAL socket open

TUBE	LOCATION	PIN #1	PIN #2	PIN #3	PIN #4	PIN #5	PIN #6	PIN #7	PIN #8	PIN #9
6005	X1	0	11	3.15[2]	3.15[2]	70	228	0		
5749	X2	-.2	.42	3.15[2]	3.15[2]	227	50	.42		
5751	X3	250	0	4.8	3.15[2]	3.15[2]	250	0	4.8	3.15[2]
5Y3W	X4	N.C.	420[1]	N.C.	525[2]	N.C.	525[2]	N.C.	420[1]	
0B2	X5	250	N.C.	N.C.	N.C.	250	N.C.	147		
0A2	X6	147	N.C.	N.C.	N.C.	147	N.C.	0		

1. AC filament voltage of X4 measured between pins #2 and #8 = 5.0 volts.

2. AC volts.

All measurements taken to ground with a 20,000 ohms-per-volt multimeter.

a. Be careful when the instrument is removed from its cabinet, dangerous voltages are exposed.

b. Careless replacement of parts often causes new faults. Therefore, observe the following points.

(1) Before a part is unsoldered, note the position of the leads. If the part, such as a transformer, has a number of connections tag each of the leads to it.

(2) Be careful not to damage other leads by pulling or pushing them out of the way.

(3) Do not allow drops of solder to fall into the set since they may cause short circuits.

(4) A carelessly soldered connection may create a new fault. It is very important to make well soldered joints since a poorly soldered joint is one of the most difficult faults to find.

(5) Do not disturb the adjustments of the controls on the chassis having screwdriver slots.

10. TROUBLE SHOOTING CHART.

The following chart is supplied as an aid in locating trouble in the C.I. Meter. This chart lists the symptoms which the repairman observes while making a few simple tests. The chart also indicates how to localize trouble quickly to individual stages of the C.I. Meter. Once the trouble has been localized to a stage or circuit, voltage and resistance measurements of this stage or circuit ordinarily should be sufficient to isolate the defective part. Normal voltage and resistance measurements are given in Tables 5-1 and 5-2.

TABLE 5—3. TROUBLE SHOOTING CHART

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
SELECTOR switch in OPERATE position		
1. Pilot lamp does not light, unit inoperative.	a. Cord not plugged into AC power source or line cord open.	a. Insert power plug into power line outlet.
	b. Fuse F1 blown out.	b. Replace fuse, check T1, V4, and C10.

TABLE 5—3. TROUBLE SHOOTING CHART, (CONT'D)

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
	c. ON-OFF switch defective (Part of S4).	c. Check and replace if defective.
	d. Voltage Change-Over switch defective.	d. Check and replace if defective.
	e. Transformer T1 open.	e. Check and replace if defective.
2. Pilot lamp lights dimly (on 115 volt source).	a. Voltage Change-Over switch S6 set for 230 v operation.	a. Set correctly.
3. Unit operates, voltmeter is off-scale to the left, zero cannot be adjusted.	a. 5751 tube (V3) defective.	a. Test tube and check tube socket voltages.
	b. R18, R19, or C1 defective.	b. Check the three components, if defective, replace.
	c. J2 shorted to ground.	c. Check for broken jack and/or broken insulating washers on jack.
	d. Defective contact on switch S4.	d. Check and replace if defective.
4. Unit not oscillating, voltmeter reads upscale, zero cannot be adjusted.	a. R23 or R24 defective.	a. Check and replace if defective.
	b. Defective contact on switch S4.	b. Check and replace if defective.
5. Voltage regulator tubes do not light.	a. Rectifier tube V4 defective.	a. Test and replace if defective.

TABLE 5—3. TROUBLE SHOOTING CHART, (CONT'D)

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
	b. Regulator tubes V5 or V6 defective.	b. Test and replace if defective.
	c. High voltage winding of T1 open, rectifier tube filament winding open.	c. Check and replace T1 if defective, check ground on pin #11 of T1.
	d. L3 open.	d. Check and replace if defective.
	e. R32 or R33 open.	e. Check and replace if defective.
	f. C1, C9, C10, or C11 shorted.	f. Check and replace if defective.
6. No reading or deflection of voltmeter with calibrating resistor in CRYSTAL socket.	a. DRIVE VOLTAGE control and/or GAIN control set too low.	a. Advance both controls clockwise.
	b. A-R switch at A.	b. Turn to R position.
	c. Meter defective.	c. Check and replace if defective.
	d. Calibrating resistor open.	d. Check resistor.
	e. Wiring shorted or open.	e. Check continuity.
	f. 6005 tube (V1) defective.	f. Test tube and replace if defective.
	g. 5749 tube (V2) defective.	g. Test tube and replace if defective.

TABLE 5–3. TROUBLE SHOOTING CHART, (CONT'D)

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
	h. Resistor open or a capacitor open or shorted.	h. Check components in oscillator circuit. Measure the voltage and resistance at the tube socket pins.
7. Voltmeter inaccurate.	a. Voltmeter zero and full-scale adjust controls not set properly.	a. Readjust voltmeter as per the procedure in the book.
	b. Voltmeter tube 5751 (V3) defective.	b. Test tube and replace if defective.
	c. Meter defective.	c. Check meter and replace if defective.
	d. Too small a value of resistance in CRYSTAL socket.	d. Use minimum value of resistance as per Table 4-1.
8. Unit operates erratically, amplitude of oscillation increases very rapidly when using a crystal unit.	a. Defect in AGC circuit.	a. Check R12, R15, and R14. Check germanium diode CR-1.
9. Ohmmeter does not work.		
a. With OHMMETER socket open, no zero ohm reading obtained on any range.	a. Switch S5 defective.	a. Check switch and replace if defective.
	b. Defective 0A2 tube (V6).	b. Test tube and replace if defective.

TABLE 5—3. TROUBLE SHOOTING CHART, (CONT'D)

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
	c. Switch S4 defective.	c. Check switch and replace if defective.
	d. OHMMETER ZERO ADJUST control not set properly.	d. Rotate control for a zero ohm reading.
b. Ohmmeter works on two ranges only.	a. Divider network associated with faulty range, defective.	a. Check fixed resistor R25, R27, or R29 and variable resistor R26, R28, or R30.
c. Ohmmeter inaccurate.	a. Divider network and/or OHMMETER ZERO ADJUST control not adjusted properly.	a. Align circuit as explained in the instruction book.
	b. Fixed resistors changed value R21, R25, R27, and R29.	b. Check resistance values and replace if defective.
	c. Meter defective.	c. Check and replace if defective.
10. Excessive hum in output.	a. Open filter capacitor in power supply.	a. Check C10 by replacing it with a new capacitor.
	b. Heater to cathode short in V1 or V2.	b. Test tubes and replace if defective.
11. Intermittent operation.	a. Defective tube, resistor, or capacitor.	a. With an insulated prod, gently tap and move all tubes, resistors, capacitors, and soldered connections.

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
E21	ACTUATOR, bolted to subminiature switch S5.	Actuates S5.	HA-5528
C1A, B&C	CAPACITOR, fixed, paper-dielectric: three sections, .5 mf capacity per section; ±20%; 600 v DC.	Cathode and screen by-pass for V1. Cathode by-pass for V3.	HA-5526
C2	CAPACITOR, fixed, paper-dielectric: .1 mf; ±10%; 200 v DC.	Coupling between V1 and V2.	H-1007-67
C3	CAPACITOR, variable: capacity, 105 mmf max - 9.5 mmf min; 1000 v RMS, 60 cyc.	Calibrated load capacitor.	HA-5556
C4	CAPACITOR, fixed, paper-dielectric: .006 mf; ±10%; 200 v DC.	DC isolation for crystal unit.	H-1080-89
C5	CAPACITOR, fixed, paper-dielectric: .25 mf; ±20%; 600 v DC.	Screen by-pass for V2.	HA-5525
C6	CAPACITOR, variable: two sections, 14.5 to 539.5 mmf per section.	Tuning, adjustable.	HA-6521
C7	CAPACITOR, variable: capacity, 3.0 mmf min to 12 mmf max.	Trimmer for C6.	HA-5531
C8	CAPACITOR, fixed, paper-dielectric: .01 mf; ±10%; 400 v DC.	Feedback coupling between V2 and V1.	H-1080-88
C9	CAPACITOR, fixed, paper-dielectric: Same as C8.	Isolates DC from output jack J1.	
C10A, B&C	CAPACITOR, fixed, electrolytic: 18-18-18 mf; 450 v DC.	B+ supply filter.	HA-5527
C11	CAPACITOR, fixed, paper-dielectric: .1 mf; ±20%; 600 v DC.	By-pass for VR tubes.	H-1007-68
O1	CLAMP, tube: stainless steel.	Holds tube V4 in its socket.	HA-4499
O2	CLAMP, tube: stainless steel.	Holds capacitor C10 in its socket.	HA-6097

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
L1	COIL, toroid: sealed, 249 mh.	Tuning coil for 10-25 kc range.	HA-6524
L2	COIL, toroid: sealed, 36.8 mh.	Tuning coil for 25-70 kc range.	HA-6523
L3	COIL, toroid: sealed, 4.7 mh.	Tuning coil for 70-200 kc range.	HA-6522
L4	COIL, toroid: sealed, 1.11 mh.	Tuning coil for 200-450 kc range.	HA-6525
L5	COIL, slug tuned: center inductance 0.243 mh at 790 kc.	Tuning coil for 450-1100 kc range.	
P1	CONNECTOR, plug: w/cable clamp; 2 flat male contacts.	Power plug.	HA-4732
P2	CONNECTOR, plug: male.	Connects RF cable to C.I. Meter.	HA-5956
J1	CONNECTOR, receptacle: coaxial; female.	RF output jack.	HA-5535
CR1	DIODE, germanium.	AGC rectifier.	HA-5537
F1	FUSE, cartridge: 2 amp.	Protection in AC input circuit.	HA-1289
F2	FUSE, cartridge: Same as F1.	Spare fuse.	
E2	FUSEHOLDER: extractor post type; 125 v, 15 amp.	Holder for fuse F1.	HA-4109
E3	FUSEHOLDER: Same as E2.	Holder for spare fuse F2.	
L6	INDUCTOR, power: 10 hy, 90 ma DC, 180 ohms.	B+ supply filter.	HB-6528
J2	JACK, telephone: single closed circuit; 2 conductor.	Voltmeter metering jack.	HA-5534
E9	KNOB: pointer; black bakelite.	Operates S1.	HA-5224

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
E10	KNOB: Same as E9.	Operates S2.	
E11	KNOB: Same as E9.	Operates S3.	
E12	KNOB: Same as E9.	Operates S4.	
E13	KNOB: Same as E9.	Operates R13.	
E14	KNOB: Same as E9.	Operates R20.	
E15	KNOB: round, fluted; black plastic.	Operates C6.	HA-6532
E16	KNOB: round; black plastic.	Operates R49.	HA-6538
E17	KNOB: Same as E16.	Operates R50.	
E18	KNOB: Same as E16.	Operates R51.	
E1	LAMP, incandescent: 6-8 v, 0.15 amp; miniature bayonet base; brown bead.	Indicator of power ON.	HA-1045
I1	LIGHT, indicator: w/lens; 1/2" ruby jewel; for miniature bayonet base.	Holder for indicator lamp.	HA-3734
M1	METER, ammeter: 0-100 ma basic movement; ohmmeter scale; 0-infinity voltmeter scales; 0-5, 0-10, 0-25.	Measures volts and ohms.	HB-5671
R1	RESISTOR, fixed comp: 100K, ±5%, 1/2 w.	Grid return for V1.	H-1009-348
R2	RESISTOR, fixed comp: 220 ohms, ±5%, 1 w.	Cathode bias for V1.	H-1009-316
R3	RESISTOR, fixed WW: 4K, ±5%, 17 w.	Plate load for V1.	H-1100-160
R4	RESISTOR, fixed comp: 100 ohms, ±5%, 1 w.	Part of plate load resistor for V1.	H-1009-182
R5	RESISTOR, fixed accurate: 1.5K, ±1%, 1/2 w.	Voltage divider.	H-1510-100
R6	RESISTOR, fixed accurate: 500 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-101

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R7	RESISTOR, fixed accurate: 250 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-102
R8	RESISTOR, fixed accurate: 150 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-103
R9	RESISTOR, fixed accurate: 50 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-104
R10	RESISTOR, fixed accurate: 25 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-105
R11	RESISTOR, fixed accurate: 32 ohms, ±1%, 1/2 w.	Voltage divider.	H-1510-106
R12	RESISTOR, fixed comp: 82K, ±5%, 1/2 w.	AGC limiting.	H-1009-379
R13	RESISTOR, variable comp: 1K, ±10%, 1 w.	GAIN control on front panel.	HA-5524
R14	RESISTOR, fixed comp: 1 meg, ±5%, 1/2 w.	Grid return for V2.	H-1009-378
R15	RESISTOR, fixed comp: 51K, ±5%, 1/2 w.	Diode load.	H-1009-102
R16	RESISTOR, fixed comp: 68 ohms, ±5%, 1/2 w.	Cathode bias for V2.	H-1009-243
R17	RESISTOR, fixed comp: 100K, ±5%, 1 w.	Screen dropping for V2.	H-1009-160
R18	RESISTOR, fixed comp: Same as R1.	Cathode bias for V3.	
R19	RESISTOR, fixed comp: Same as R15.	Cathode bias for V3.	
R20	RESISTOR, variable comp: 1K, ±10%. 1/4 w.	OHMMETER ZERO ADJUST on front panel.	HA-5516
R21	RESISTOR, fixed comp: 1.5K, ±5%, 1/2 w.	Meter dampening.	H-1009-365

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R22	RESISTOR, variable comp: Same as R20.	Voltmeter full-scale adjust.	
R23	RESISTOR, fixed comp: 300K, ±5%, 1/2 w.	Voltage divider.	H-1009-380
R24	RESISTOR, variable comp: 10K, ±10%, 1/4 w.	VOLTMETER ZERO ADJUST.	HA-5517
R25	RESISTOR, fixed accurate: 800K, ±1%, 1/2 w.	Ohmmeter voltage divider for R x 100 range.	H-1510-107
R26	RESISTOR, variable comp: 250K, ±10%, 1/4 w.	Half-scale calibrate for R x 100 range.	HA-5518
R27	RESISTOR, fixed accurate: 750K, ±1%, 1/2 w.	Ohmmeter voltage divider for R x 10 range.	H-1510-108
R28	RESISTOR, variable comp: 25K, ±10%, 1/4 w.	Half-scale calibrate for R x 10 range.	HA-5519
R29	RESISTOR, fixed accurate: 240K, ±1%, 1/2 w.	Ohmmeter voltage divider for R x 1 range.	H-1510-109
R30	RESISTOR, variable comp: 500 ohms, ±10%, 1/4 w.	Half-scale calibrate for R x 1 range.	HA-5520
R31	RESISTOR, fixed WW: 500 ohms, ±5%, 12 w.	Decoupling.	H-1100-162
R32	RESISTOR, fixed WW: 1.1K, ±5%, 17 w.	B+ supply filter.	H-1100-161
R33	RESISTOR, fixed WW: Same as R32.	B+ supply filter.	
R34	RESISTOR, fixed WW: 4K, ±5%, 12 w.	Decoupling.	H-1100-159
R35	RESISTOR, fixed accurate: 3K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-86

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R36	RESISTOR, fixed accurate: 4K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-87
R37	RESISTOR, fixed accurate: 5K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-88
R38	RESISTOR, fixed accurate: 6K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-89
R39	RESISTOR, fixed accurate: 7K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-90
R40	RESISTOR, fixed accurate: 8K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-91
R41	RESISTOR, fixed accurate: 10 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-92
R42	RESISTOR, fixed accurate: 20 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-93
R43	RESISTOR, fixed accurate: 50 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-94
R44	RESISTOR, fixed accurate: 75 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-95
R45	RESISTOR, fixed accurate: 100 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-96
R46	RESISTOR, fixed accurate: 125 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-97
R47	RESISTOR, fixed accurate: 150 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-98
R48	RESISTOR, fixed accurate: 200 K, ±1%, 1/2 w.	Fixed calibrating resistor.	H-1510-99
R49	RESISTOR, variable comp: 500 K, ±20%, 1/4 w.	Variable calibrating resistor.	HA-5521
R50	RESISTOR, variable comp: 50 K, ±20%, 1/4 w.	Variable calibrating resistor.	HA-5522

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R51	RESISTOR, variable comp: 5 K, ±20%, 1/4 w.	Variable calibrating resistor.	HA-5523
E4	SHIELD, electron tube: locking type.	Tube shield for V2.	HA-4781
E5	SHIELD, electron tube: locking type.	Tube shield for V3.	HA-4782
E6	SHIELD, electron tube: locking type.	Tube shield for V1.	HA-4731
E7	SHIELD, electron tube: Same as E6.	Tube shield for V5.	
E8	SHIELD, electron tube: Same as E6.	Tube shield for V6.	
X1	SOCKET, turret: 7 pin w/shield base.	To hold V1.	HA-5573
X2	SOCKET, turret: Same as X1.	To hold V2.	
X3	SOCKET, turret: 9 pin w/shield base.	To hold V3.	HA-5574
X4	SOCKET, tube: 8 contact.	To hold V4.	HA-4787
X5	SOCKET, tube: 7 contact.	To hold V5.	HA-4789
X6	SOCKET, tube: Same as X5.	To hold V6.	
X7	SOCKET, crystal: 2 contact.	CRYSTAL socket on front panel.	HA-4558
X8	SOCKET, crystal: Same as X7.	OHMMETER socket on front panel.	
X9	SOCKET, tube: Same as X4.	To hold C10.	
X10	SOCKET, tube: 8 contacts.	Connector for octal base crystal holders.	HA-5572

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
S1	SWITCH, rotary: 8 positions, 1 section.	DRIVE VOLTAGE switch on front panel.	HB-5579
S2	SWITCH, rotary: 2 positions, 1 section.	A-R switch on front panel.	HB-6526
S3	SWITCH, rotary: 5 positions, 1 section.	FREQUENCY RANGE switch on front panel.	HB-6527
S4	SWITCH, rotary: 5 positions, 3 sections.	SELECTOR switch on front panel.	HB-5576
S5	SWITCH, subminiature: single-pole, double-throw.	OHMMETER socket shorting switch.	HA-4843
S6	SWITCH, toggle: DPDT.	Voltage change-over switch.	HA-3710
E19	TERMINAL STRIP: 2 terminal; bakelite strip.	Support for C9.	HA-1727
E21	TERMINAL STRIP: Same as E19.	Power cable terminals.	
E20	TERMINAL STRIP: 3 terminal.	Support for R25, R27, and R29.	HA-5570
T1	TRANSFORMER, power: two separate primaries, each 115 volts, 50-1000 cps; secondaries, 1050 volts CT, 100 ma; 5.0 v, 2 amp; 6.3 v CT, 2 amp.	Power transformer.	HC-5678
V1	TUBE, electron: miniature beam power amplifier, 6005.	Driver amplifier.	HA-5529
V2	TUBE, electron: miniature RF amplifier pentode, 5749.	Phase-inverting-amplifier.	HA-5530
V3	TUBE, electron: miniature twin triode, 5751.	Voltmeter.	HA-4835

TABLE 5—4. TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
V4	TUBE, electron: full-wave, high-vacuum rectifier, 5Y3WGT.	B+ supply rectifier.	HA-5222
V5	TUBE, electron: voltage regulator, 0B2.	Voltage regulator.	HA-3666
V6	TUBE, electron: voltage regulator, 0A2.	Voltage regulator.	HA-3665

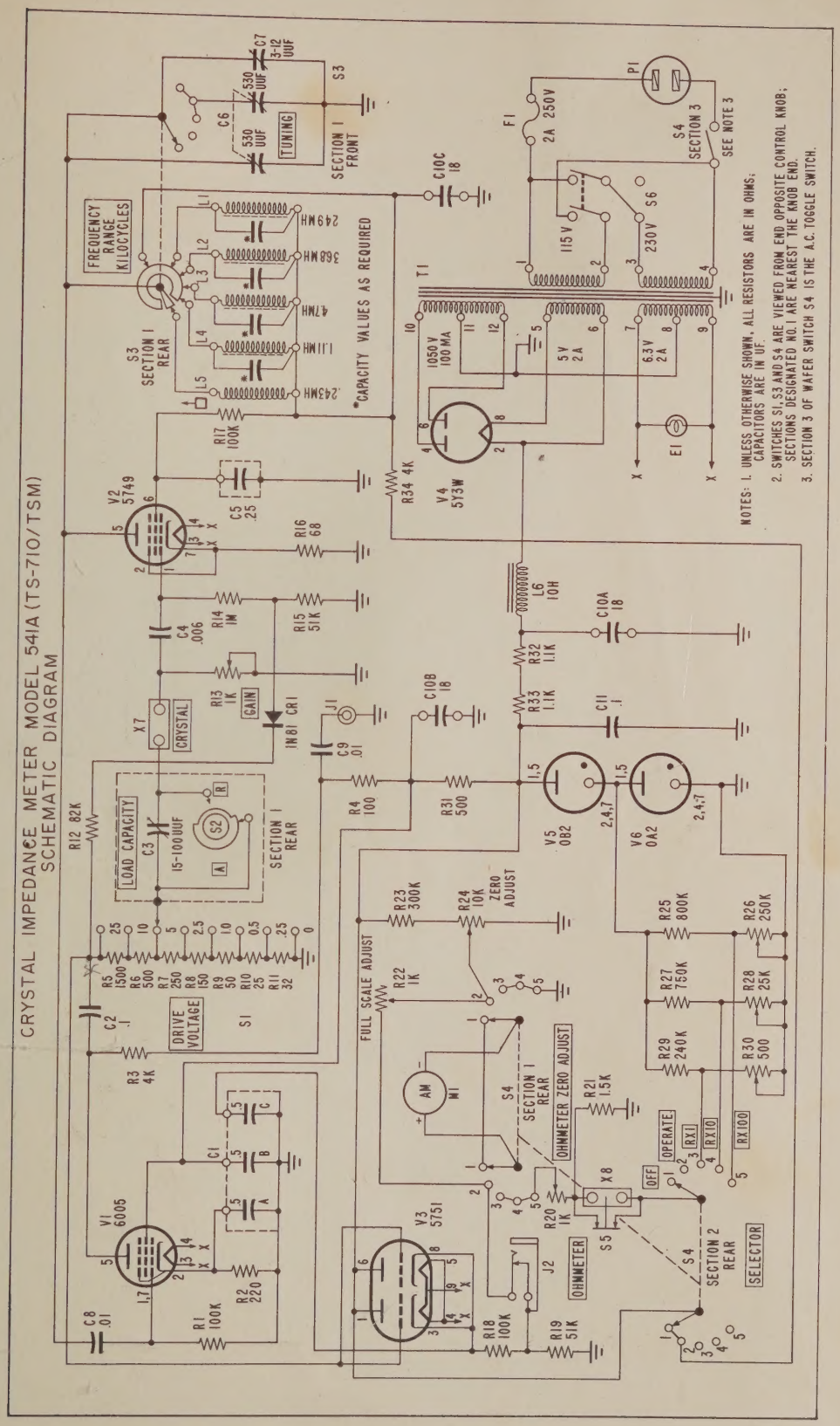
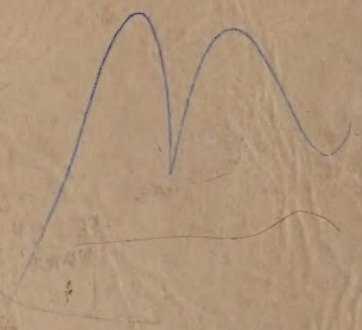


Figure 9. Schematic Diagram of Crystal Impedance Meter Model 541A



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.084

4.284

4.116